# PARKING STRUCTURE LIGHTING PERFORMANCE SPECIFICATION

## **PART 1 –** GENERAL

### 1.1 SUMMARY

The parking structure lighting performance specification is intended to provide adequate illumination in parking structures (also known as parking garages) and save energy by reducing the installed power density of equipment below code as well as using controls to further reduce energy consumption. Revisions to this specification may occur in the future.

### 1.2 REFERENCES

A. The publications listed below form a part of this specification to the extent referenced. Publications are referenced within the text by the basic designation only.

B. American National Standards Institute (ANSI)

**1.** ANSI C62.41.1-2002 – IEEE Guide on the Surge Environment in Low-Voltage (1000V and less) AC Power Circuits

**2.** ANSI C62.41.2-2002 – IEEE Recommended Practice on Characterization of Surges in Low-Voltage (1000W and less) AC Power Circuits

**3.** ANSI/NEMA/ANSLG C78.376-2001 – Specification American National Standard for the Chromaticity of Solid State Lighting Products

**4.** ANSI/NEMA/ANSLG C78.377-2008 – American National Standard for the Chromaticity of Solid State Lighting Products

**5.** ANSI C82.SSL1 – SSL Drivers (in ANSI development)

**6.** ANSI C82.11-2002 – For Lamp Ballasts, High Frequency Fluorescent Lamp Ballasts – Supplements

**7.** ANSI C82.77-2002 – Harmonic Emission Limits – Related Power Quality Requirements for Lighting Equipment

C. American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE)

**1.** Std. 90.1-2010 – ANSI/ASHRAE/IENSA Standard 90.1 Energy Standard for Buildings Except Low-Rise Residential Buildings

D. American Society for Testing and Materials International (ASTM)

**1.** ASTM A 36 – Structural Steel

**2.** ASTM A 123 – Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products

**3.** ASTM A 153 – Zinc Coating (Hot-Dip) on Iron and Steel Hardware

**4.** ASTM A 595 – Steel Tubes, Low-Carbon, Tapered for Structural Use

**5.** ASTM F 1554 – Anchor Bolts, Steel, 36, 55, And 105-Ksi Yield Strength

6. ASTM B117-97 – Standard Practice for Operating Salt Spray (Fog) Apparatus
7. ASTM G53 – Standard Practice for Operating Light and Water Exposure Apparatus (Fluorescent UV – Condensation Type) for Exposure of Nonmetallic Materials

E. European Commission (EC)

1. RoHS Directive 2002/95/EC, "On the restriction of the use of certain hazardous substances in electrical and electronic equipment"
2. WEEE Directive 2002/96/EC, "On waste electrical and electronic equipment"

F. Federal Communications Commission (FCC)

1. CFR Title 47 Part 18 Subpart C, "RF Lighting Devices"

G. Illuminating Engineering Society of North America (IESNA)

1. DG-13-98, Guide for the Selection of Photocontrols for Outdoor Lighting Applications
2. LM-10-96, Photometric Testing of Outdoor Fluorescent Luminaires
3. LM-64-01, Photometric Measurements of Parking Areas
4. LM-79-08, IESNA Approved Method for the Electrical and Photometric Measurements of Solid-Sate Lighting Products
5. LM-80-08, IESNA Approved Method for Measuring Lumen Maintenance of LED Light Sources
6. RP-20-98, Recommended Practice for Lighting Parking Facilities

H. Institute of Electrical and Electronics Engineers (IEEE)

1. ANSI/IEEE C2 – National Electrical Safety Code

I. International Electrotechnical Commission (IEC)

1. IEC 60529 – Degrees of Protection provided by enclosures (IPCode)

J. Joint Electron Device Engineering Council (JEDEC)

1. JEDEC J-STD-020D.01, "Joint IPC/JEDEC standard for moisture/reflow sensitivity classification for nonhermetic solid state surface-mount devices"
2. JEDEC JESD22-A104D, "Temperature cycling"
3. JEDEC JESD22-A107B, "Salt atmosphere"
4. JEDEC JESD22-A108C, "Temperature, bias, and operating life"
5. JEDEC JESD22-A114F, "Electrostatic discharge (ESD) sensitivity testing human body model (HBM):"
6. JEDEC JESD22-B104C, "Mechanical shock"

K. Japan Electronics and Information Technology Industries Association (JEITA)

**1.** JEITA EIAJ ED-4701/100, "Environmental and endurance test methods for semiconductor devices (Life test I)"

**2.** JEITA EIAJ ED-4701/200, "Environmental and endurance test methods for semiconductor devices (Life test II)"

**3.** JEITA EIAJ ED-4701/300, "Environmental and endurance test methods for semiconductor devices (Stress test I)"

**4.** JEITA EIAJ ED-4701/400, "Environmental and endurance test methods for semiconductor devices (Stress test II)"

L. National Electrical Manufacturers Association (NEMA)

**1.** LSD23-2002 – Recommend Practice – Lamp Seasoning for Fluorescent Dimming Systems

**2.** WD 7-2000 – Occupancy Motion Sensors

M. National Fire Protection Association (NFPA)

**1.** NFPA 70 – National Electrical Code

N. National Institute of Standards and Technology (NIST)

**1.** National Voluntary Laboratory Accreditation Program (NVLAP) for Energy Efficient Lighting Products

O. Underwriter's Laboratory (UL)

**1.** UL 1598 – Luminaires

**2.** UL 935 – Standard for Fluorescent-Lamp Ballasts

P. Restriction of Hazardous Substances (RoHS)

**1.** http://www.dtsc.ca.gov/HazardousWaste/UniversalWaste/RoHS_Lighting.cfm?CFID=11592115&CFTOKEN=49724139#Decision_Trees_for_Lighting

## 1.3 SECTION INCLUDES

Luminaires, including light sources, ballasts/drivers, wiring, and lighting controls for lighting in parking structures.

## 1.4 QUALITY ASSURANCE

A. Testing shall be conducted per the applicable IESNA and ANSI approved methods for products using the applicable sources.

**1.** Provide a test report from a laboratory that is either:

**a.** Accredited by NVLAP or one of its Mutual Recognition Arrangement (MRA) signatories. If the laboratory used for this test is accredited by

NVLAP or one of its MRA signatories it must also have a scope of accreditation that includes the method of measurement reference standard for this performance characteristic.

**b.** Or CALiPER recognized laboratories: http://www1.eere.energy.gov/buildings/ssl/test_labs.html.

**2.** LM-79 and LM-80 laboratory test results must be produced using the specific LED package(s)/module(s)/array(s) and power supply combination that will be used in production.

## 1.5 SITE LIGHTING SYSTEM PERFORMANCE

### A. Energy Conservation

**1.** Lighting within the parking structure (excluding dedicated emergency lighting) shall not exceed a maximum of 0.18 W/ sf (>10% less than Std. 90.1-2010) lighting power density (LPD).

### B. Light Loss Factors (LLF)

**1.** Assume Luminaire Dirt Depreciation (LDD): 0.82 for all luminaires.

**2.** Assume the following Lamp Lumen Depreciation (LLD):

**a.** Per RP-20-98, section 6.1.4. Lumen Maintenance: Lumen depreciation relates to the light output throughout the life of the lamp as a direct result of electrode deterioration and lamp blackening. Each design should provide the required minimum lighting levels at time of relamping. Therefore, design should be based on the relamping program to be used (see Section 8.2.2)

**b.** Per RP-20-98, section 8.2.2. Lamp Lumen Depreciation (LLD). "A light source's gradual loss of lumen output due to normal in-service aging characteristics is subject to wide variances depending upon the type of source used. Manufacturer's published data for each type and size can be use to predict the rate and to estimate lamp mortality. These predictable losses and life expectancies should be used to develop a program of planned maintenance for lamp replacement based upon the values of illuminance levels established for the lighting design, and to achieve the most favorable economy of lamp replacement. Group relamping normally results in the lower overall replacement cost and provides the greatest service level through maintaining a low lamp lamp outage rate. Group relamping at about 70 percent of rated life represents good practice. If spot (burnout only) lamp replacement is used, a very low lamp burn out (LBO) factor should be considered in the design such as 50 percent (LBO = 0.5)."

**c.** Estimated LLD values at fluorescent/induction (70% of rated life) and LEDs (70% of initial light output) for the light sources allowed within this specification:

i. 0.92 for fluorescent luminaires
ii. 0.70 for LED-dedicated luminaires, an alternate value may be used

based on the use of the Site defined performance method. See Section 2.4 D for calculation.

iii. 0.60 for induction luminaires

**3.** Luminaire Ambient Temperature Factor: Assume the appropriate effects from temperature on the lumen output of the luminaire. Parking structures are typically unconditioned spaces, not enclosed spaces; the lighting is extremely subject to the ambient temperature. Therefore, design and life calculations should take in account the effect of temperature on source.

**a.** Locations where the mean number of days annually with a minimum temperature equal or less to 0° C (32° F) number more than 120 (see Appendix E) are considered "COLD" places. Use a Luminaire Ambient Temperature Factor (LATF) of:

- 0.8 in the fluorescent calculations
- 0.8 in the induction calculations
- 1.0625 in the LED calculations

**b.** Locations where the mean number of days annually with a minimum temperature equal or less to 0 C (32 F) number less than 120 (see Appendix E) are considered "WARM" places. LATF of:

- 1.0 in the fluorescent calculations
- 1.0 in the induction calculations
- 0.90 in the LED calculations.

**c.** Refer to Appendix F for sample temperature information for different locations in the U.S.

C. Lighting Requirements

| Area of Parking Structure | Minimum Horizontal[1] Requirement | | Uniformity Max:Min | Uniformity CV | Vertical[2] Illuminance Requirement | |
|---|---|---|---|---|---|---|
| | Lux | fc | | | Lux | fc |
| Covered Parking Areas (Basic) | 10.0 | 1.0 | 7:1 | 0.38 | 0.5 | 0.5 |
| Ramps | | | | | | |
| Day | 20.0 | 2.0 | 10:1 | 0.41 | 10.0 | 1.0 |
| Night | 10.0 | 1.0 | 10:1 | 0.41 | 5.0 | 0.5 |
| Vehicle Entry/Exit | | | | | | |
| Day[3] | 500.00 | 50.0 | 10:1 | 0.41 | 250.00 | 25.0 |
| Night | 10.00 | 1.0 | 10:1 | 0.41 | 5.0 | 0.5 |
| Uncovered Parking Areas (Top Deck)[4] | 0.75 (Min) | | 10:1 | 0.41 | 0.4 | |

Note:

1. Measured on the parking surface, without any shadowing effect from parked vehicles or columns.
2. Vertical measurements shall be taken at 5' (1.5m) vertically
3. Contributions from daylight may be factored into these values.
4. Uncovered parking requirements **not** from RP-20.

## 1.6 SUBMITTALS

A. Performance Reports – Submit the following for approval when required by the Site owner:

**1.** Computer generated photometric analysis of proposed **DAY 1** (defined as the initial illuminance values), of the lighting installation, submittal should include the following requirements:

**a.** Provide horizontal illuminance measurements (in footcandles) at grade. Spacing between measurement points shall be 5' on center.

**b.** Computer calculation should use the following applicable LLF values: 1.0 LLD and 1.0 LDD.

**2.** Computer generated photometric analysis of proposed **FUTURE DATE (**defined as assuming numerous thousands of hours of operation specified by site) of the lighting installation, submittal should include the following requirements:

**a.** Provide horizontal illuminance measurements (in footcandles) at grade. Spacing between measurement points shall be 10' on center.

**b.** Computer calculation should use the LLF values as specified above.

B. Fluorescent Product Data: For each type of lighting luminaire, arranged in order of luminaire designation. Include data on features, accessories, finishes, and the following:

**1.** Physical description of luminaire including dimensions.

**2.** Ballast including: ballast type (e.g., programmed rapid-start); Ballast Factor; catalog code; input watts for ballast when operating the applicable number of light sources, and device reliability.

**a.** Device reliability shall be calculated per MIL-HDBK-217F(2) using Mean Time Before Failures (MTBF) as metric including load condition and temperature under which MTBF was calculated.

**3.** Initial lumen output of light source and operating temperature in degree Celsius (°C) at which the lumens are rated.

**4.** Luminaire Coefficient of Utilization data for reflectance values of 30/0/20 for both RCRs: 2 & 3.

**5.** Luminaire efficiency (also known as fixture efficiency).

**6.** Mean (also known as design) lumen output of light source and percentage of rated life in which mean/design value derived.

7. Target Efficacy Rating (TER)[1] of luminaire (Initial lumens x ballast factor x (average of CU values for 30/0/20 at RCR 2&3) / ballast input watts).
8. Mean Lumens Per Watt of Lamp + Ballast (mean lumens / ballast input watts).
9. Luminaire Efficacy of luminaire (Initial lumens x ballast factor x luminaire efficiency / ballast input watts).
10. Table of zonal lumen output in 10° vertical increments showing both the lumen value and the percentage of total output per 10° increment.
11. Correlated Color Temperature (CCT) of light source.
12. Color-Rendering Index (CRI) of light source.

C. LED Product Data: For each type of lighting Luminaire, arranged in order of luminaire designation. Include data on features, accessories, finishes, and the following:

1. Physical description of luminaire including dimensions.
2. Driver including: Driver Efficiency; catalog code; input watts, and device reliability.
    a. Device reliability shall be calculated per MIL-HDBK-217F(2) using Mean Time Before Failures (MTBF) as metric including load condition and temperature under which MTBF was calculated.
3. Luminaire Lighting Facts Label (www.lightingfacts,com)
    a. It is acknowledged that a label is not possible for every possible configuration of a product line. However, the label is important. Manufacturer must demonstrate the label for at least one parking structure luminaire that they manufacture.
4. Luminaire photometric reports per IES LM-79 including: laboratory name, report number, date, luminaire catalog number, luminaire, and light source specifications.
5. Initial lumen output of luminaire and ambient temperature and drive current at which the lumens are rated.
6. Luminaire Coefficient of Utilization data for reflectance values of 30/0/20 for both RCRs: 2 & 3for LED luminaires used in the covered section of the parking structure.
7. Luminaire (also known as fixture) efficacy.
8. Target Efficacy Rating (TER) of luminaire (Initial lumens x (average of CU values for 30/0/20 at RCR 2&3) / input watts) – only for LED luminaires used in the covered section of the parking structure.

[1]TER – Target Efficacy Ratings is a metric developed by the National Manufacturers Electrical Association (NEMA). This metric supercedes Luminaire Efficacy Rating (LER). More information can be found about TER in NEMA LE6-2008 and can be found at http://www.nema.org/stds/le6.cfm. This specification requires the necessary data for TER calculations in section 1.6 Submittals.

**9.** Table of zonal lumen output in 10° vertical increments showing both the lumen value and the percentage of total output per 10° increment.

**10.** Correlated Color Temperature (CCT) of light source with Duv values.

**11.** Color-Rendering Index (CRI) of light source.

**12.** A minimum of 6,000 hours of continuous operation of the LEDs at three different temperatures per LM-80.

D. Induction Product Data: For each type of lighting luminaire, arranged in order of luminaire designation. Include data on features, accessories, finishes, and the following:

**1.** Physical description of luminaire including dimensions.

**2.** Generator Information including: Generator Efficiency (rated lamp wattage/input wattage); catalog code; input watts, and device reliability

**a.** Device reliability shall be calculated per MIL-HDBK-217F(2) using MTBF as metric including load condition and temperature under which MTBF was calculated.

**3.** Luminaire photometric reports per IESNA LM-10-96 including: laboratory name, report number, date, luminaire catalog number, luminaire, and light source specifications

**4.** Initial lumen output of light source and temperature at which the lumens are rated

**5.** Mean (also known as design) lumen output of light source and percentage of rated life in which mean/design value derived

**6.** Luminaire Coefficient of Utilization data for reflectance values of 30/0/20 for both RCRs: 2 & 3

**7.** Luminaire (also known as fixture) efficacy

**8.** Target Efficacy Rating (TER) of luminaire (Initial lumens x (average of CU values for 30/0/20 at RCR 2&3) / input watts)

**9.** Table of zonal lumen output in 10° vertical increments showing both the lumen value and the percentage of total output per 10° increment

**10.** Correlated Color Temperature (CCT) of light source

**11.** Color-Rendering Index (CRI) of light source

E. Provide documentation of the expected useful life as defined in Section 2.4 D including the testing and calculation of useful life and verification of site lighting performance at that life. If the Site defined performance method is used, document the use of LM-80 test data, the specific extrapolation procedure used, the interpolation between the three sets of LM-80 data, and all calculations applied in deriving the proposed LLD and useful life.

F. Provide safety certification and file number as required for the luminaire family which shall be listed, labeled, or identified per the National Electric Code (NEC). Applicable testing bodies are determined by the US Occupational Safety Health Administration

(OSHA) as Nationally-Recognized Testing Laboratories (NRTL) and include: CSA (Canadian Standards Association), ETL (Edison Testing Laboratory), and UL (Underwriters Laboratory).

## 1.7 WARRANTY

A. Fluorescent Luminaire Warranty:

**1.** Provide a comprehensive written **five-year** warranty for including luminaire finish, on-site replacement of material, and workmanship. On-site replacement includes transportation, removal, and installation of new products. Finish warranty shall include warranty against failure or substantial deterioration such as blistering, cracking, peeling, chalking, or fading.

**2.** Provide a written **five-year** replacement material warranty on all power supply units (PSUs).

**3.** Provide a written **three**-year warranty that fluorescent color shift from initial color shall be less than 0.007 on the CIE 1976 (u',v') diagram. This requirement is comparable to a 7-step MacAdam ellipse.

B. LED Luminaire Warranty

**1.** Provide a comprehensive written **five-year** warranty for including luminaire finish, on-site replacement of material, and workmanship. On-site replacement includes transportation, removal, and installation of new products. Finish warranty shall include warranty against failure or substantial deterioration such as blistering, cracking, peeling, chalking, or fading.

**2.** Provide a written **five-year** replacement material warranty for defective or non-starting LED source assemblies.

**3.** Provide a written **five-year** replacement material warranty on all PSUs.

**4.** Provide a written **five-year** replacement warranty for non-maintained illuminance levels (See section 1.5 C) on all light sources (LED package, LED array, or LED module) including, but not limited to the LED die, encapsulate, and phosphor. If the expected useful life of the luminaire system as defined in Section 2.4 C is not maintained, then the manufacturer shall replace the light source(s) or luminaire as needed.

**5.** Provide a written **five**-year warranty that LED color shift from initial shall color be less than 0.007 on the CIE 1976 (u',v') diagram. This requirement is comparable to a 7-step MacAdam ellipse.

C. Induction Luminaire Warranty:

**1.** Provide a comprehensive written **five-year** warranty for including luminaire finish, on-site replacement of material, and workmanship. On-site replacement includes transportation, removal, and installation of new products. Finish warranty shall include warranty against failure or substantial deterioration such as blistering, cracking, peeling, chalking, or fading.

**2.** Provide a written **five-year** replacement material warranty on all PSUs.

**3.** Provide a written **five-year** replacement on light source.

**4.** Provide a written **five-**year warranty that the induction color shift from initial color shall be less than 0.007 on the CIE 1976 (u',v') diagram. This requirement is equivalent to a 7-step MacAdam ellipse.

**PART 2 –** PRODUCTS

2.1 GENERAL

A. Luminaire shall be the type indicated on Drawings and as specified. Luminaires of same type shall be of one manufacturer.

B. Luminaires shall be of the types and manufacturers described in the LUMINAIRE REQUIREMENTS section below, with light source, wattage and voltage as indicated on Drawings. Specific manufacturer and model number references are indicated as a standard of performance and quality; other manufacturers' models may be suppled provided the product meets or exceeds the specifications. The alternate luminaires must achieve the equal or better photometric levels and uniformity ratios.

C. All luminaires shall be baked-on enamel or powder-coated, unless otherwise specified in subsections below.

2.2 LIGHT SOURCE REQUIREMENTS

A. Fluorescent Lamps shall meet the following requirements:

**1.** Light sources in this application can be:

**a.** 4' linear T8: F32T8 (32W nominal) [ Do not use "energy saving" T8 lamps];

**b.** ≈ 4' linear T5: F28T5, F54T5HO, F49T5HO lamps;

**c.** ≈ 2' compact fluorescent linear T5: FT40, FT55, and FT80 lamps.

**2.** All lamps shall have the following characteristics:

**a.** Low-mercury meeting Toxicity Characteristic Leaching Procedure (TCLP) standards

**b.** Produce at least 2,900 lumens (initial) when measured on a reference ballast

**c.** A correlated color temperature (CCT) between: 3000 – 4100 K

**d.** A Color Rendering Index (CRI): ≥ 80

**e.** Lamp Lumen Depreciation (LLD) shall be 92% or greater at 20,000 hours

B. LED sources shall meet the following requirements:

**1.** Correlated Color Temperature (CCT): 2700 – 6500 K, Nominal and Target CCT, Duv, and tolerances listed below:

**a.** 2700 K: (2725 ± 145) / Target Duv (0.000 ± 0.006)

**b.** 3000 K: (3045 ± 175) / Target Duv (0.000 ± 0.006)

**c.** 3500 K: (3465 ± 245) / Target Duv (0.000 ± 0.006)

**d.** 4000 K: (3985 ± 275) / Target Duv (0.001 ± 0.006)

**e.** 4500 K: (4503 ± 243) / Target Duv (0.001 ± 0.006)

**f.** 5000 K: (5028 ± 283) / Target Duv (0.002 ± 0.006)

**g.** 5700 K: (5665 ± 355) / Target Duv (0.002 ± 0.006)

**h.** 6500 K: (6530 ± 510) / Target Duv (0.003 ± 0.006)

**2.** Color Rendering Index (CRI): ≥ 70

**3.** The device (LED chip or package) manufacturer shall subject all products to the tests listed in Appendix B

**4.** The device (LED chip or package) shall meet the requirements in Section 2.4 D.

C. Induction Lamps shall meet the following requirements:

**1.** Produce at least 3,500 lumens (initial) when measured on a reference generator

**2.** A correlated color temperature (CCT) between: 3,000 – 5,000 K

**3.** A Color Rendering Index (CRI): ≥ 80

**4.** Lamp Lumen Depreciation (LLD) shall be 80% or greater at 40,000 hours

## 2.3 POWER-SUPPLY UNIT (BALLAST, DRIVER, OR GENERATOR) REQUIREMENTS

A. Fluorescent ballasts shall meet the following requirements:

**1.** Ballasts shall be class P, electronic high-frequency (20 to 33 kHz or ≥ 40 kHz) programmed-rapid start type ballasts.

**2.** Ballasts shall have the following Ballast Efficacy Factors (BEF), defined: as BF x 100 / input watts

**a.** One-lamp configuration: ≥ 2.84

**b.** Two-lamp configuration: ≥ 1.48

**3.** Ballasts shall have a minimum Relative System Efficiency (RSE) of 95%, defined as BEF x Total Rated Lamp Power / 100

**4.** Ballasts shall have a Power Factor (PF) of: ≥ 0.95

**5.** Ballasts shall have a Total Harmonic Distortion (THD) of: ≤ 20%

**6.** Input Voltage: capable of 120 – 277 or 347 – 480 (±10%) volt, single phase or as required by the site

**7.** Ballasts shall be color coded per ANSI C82.11

**8.** Ballasts shall be Class A noise rated

9. Ballasts shall comply with FCC 47 cfr part 18 non-consumer RFI/EMI standards
10. Ballasts shall be Reduction of Hazardous Substances (RoHS) compliant (see http://www.rohs.eu/english/index.html)
11. Ballasts shall comply with ANSI C62.41 Category A for Transient protection.
12. Ballasts shall not contain any Polychlorinated Biphenyl (PCB)
13. Ballasts shall have a minimum starting temperature of -18° C (0° F) for standard fluorescent lamps

B. LED drivers shall meet the following requirements:

1. Drivers shall have a minimum efficiency of 85% at specified loading
2. Starting Temperature: -40° C
3. Input Voltage: capable of 120-277, 347, or 480 (±10%) volt, single phase or as required by the site
4. Power supplies can be UL Class I or II output
5. Surge Protection: The system must survive 250 repetitive strikes of "C Low" (C Low – 6kV/1.2 x 50 µs, 10kA/8 x 20 µs) waveforms at 1 minute intervals with less than 10% degradation in clamping voltage. "C Low" waveforms are as defined in IEEE/ASNI C62.41.2-2002, Scenario 1 Location Category C
6. Drivers shall have a Power Factor (PF) of: ≥ 0.90
7. Drivers shall have a Total Harmonic Distortion (THD) of: ≤ 20%
8. Drivers shall comply with FCC 47 cfr part 18 non-consumer RFI/EMI standards
9. Drivers shall be Reduction of Hazardous Substances (RoHS) compliant (see http://www.rohs.eu/english/index.html)

C. Induction generators shall meet the following requirements:

1. Generators shall have a minimum efficiency of 85%
2. Generators shall have a Power Factor (PF) of: ≥ 0.90
3. Generators shall have a Total Harmonic Distortion (THD) of: ≤ 20%
4. Input Voltage: capable of 120 to 480 (±10%) volt, single phase or as required by the site
5. Generators shall be Class A noise rated
6. Generators shall comply with FCC 47 cfr part 18 non-consumer RFI/EMI standards
7. Generators shall be Reduction of Hazardous Substances (RoHS) compliant. (see http://www.rohs.eu/english/index.html)
8. Generators shall have a minimum starting temperature of -18° C (0° F)

## 2.4 LUMINAIRE REQUIREMENTS

A. Covered Parking Structure Luminaire General Requirements

**1.** The luminaire shall produce a minimum of 20% of total output in the 60° to 70° vertical zones

**2.** Luminaires shall have a TER greater than 30

**3.** The luminaire shall have an initial ***luminaire efficacy*** greater than 60 LPW

**4.** Electrical system cavity shall be wet-location rated and be field accessible for service or repair needs.

**5.** Optical cavity shall be a minimum IP-65 as per IEC 60529.

**6.** Luminaires shall be fully assembled and electrically tested before shipment from factory.

**7.** Luminaires shall have country appropriate governing mark and certification.

**8.** Color of the luminaire shall be as specified by the site owner.

**9.** If a lens not integral to an LED is used, the luminaire optical enclosure (lens/window) shall be constructed of a one piece, UV resistant, clear, polycarbonate, acrylic or glass, sealed to IP-65.

**10.** 80% of the luminaire material by weight should be recyclable at end of life. Luminaire shall be designed for end-of-life disassembly per ISO 14021.

B. Uncovered Parking Structure Luminaire General Requirements

**1.** Luminaires used in the uncovered portion (top deck) of the parking structure can only be LED.

**2.** Luminaire shall have a maximum BUG Rating of U3-G3[2].

**3.** The luminaire shall have an initial ***luminaire efficacy*** greater than 50 LPW

**4.** Electrical system cavity shall be wet-location rated and be field accessible for service or repair needs.

**5.** Optical cavity shall be a minimum IP-65 as per IEC 60529.

C. LED-dedicated Luminaire Expected Useful Life and Depreciation

**1.** Useful Life Requirement: The useful life of the luminaire in terms of lumen output must be as specified by one of the following two methods:

**a.** Simplified $L_{70}$ threshold: A minimum of 50,000 operating hours before reaching the $L_{70}$ lumen output degradation point with no catastrophic failures. The $L_{70}$ lumen output must be capable of providing the illuminance levels and uniformity specified in Section 1.6.

**b.** Site performance method: A lifetime of the number of hours specified by the Site based on expected Site lighting use and planned replacement

[2] BUG Ratings – Refer to IESNA TM-15-07 and Addendum A for values. More information can be found at http://www.iesna.com/PDF/Erratas/TM-15-07BUGRatingsAddendum.pdf.

where the lumen output at the specified useful life must be capable of providing the illuminance levels and uniformity specified in Section 1.6.

**2.** Useful Life Testing and Verification Procedure:

**a.** Simplified $L_{70}$ threshold: Perform LM-79 testing on the luminaire at both time intervals of 0 hours and $\geq$ 6,000 hours. The luminaire shall be operated continuously in the appropriate UL 1598/153 environment except when it is removed to perform the LM-79 light output tests. If the light output determined at 6,000 hours is $\geq$ 96%, the light output determined at 0 hours, the luminaire meets the simplified $L_{70}$ threshold for useful life.

**b.** Site defined performance method:

i. Perform lumen depreciation testing per LM-80 on the light source(s) (module/array) for a minimum of 6000 hours (longer testing period is encouraged). Per LM-80, identify the case temperature measurement point ($T_s$) that is accessible to allow temporary attachment of a thermocouple for measurement of the LED temperature when installed in the luminaire. Access via a temporary hole in the housing, tightly resealed during testing with putty or other flexible sealant is allowable.

ii. Use the LM-80 test data to extrapolate the lumen depreciation of the LED module/array (lumen degradation at three temperatures) using a standard exponential decay curve fit as described in Appendix C.

iii. Identify the installed (in luminaire) operating temperature of the LED using the $T_s$ point under operating conditions as described in LM-79. Use this in-luminaire LED module/array temperature to interpolate a decay curve between the three extrapolated degradation curves derived from LM-80 and exponential decay curve fitting.

iv. From this interpolated curve, determine the lamp lumen depreciation (LLD) value and useful life that meets the needs of the Site defined hours of operation to end of useful life as well as the illuminance levels and uniformity specified in Section 1.6. for the useful life of the luminaire. Document the use of LM-80 test data, the specific extrapolation procedure used, the interpolation between the three sets of LM-80 data, and all calculations applied in deriving the proposed LLD and useful life.

## 2.5 CONTROL REQUIREMENTS

A. Daylighting Controls

**1.** All luminaires located along the perimeter zone (20' from the face of the structure) and in areas where the openness-to-wall ratio is greater than or equal to 40% shall be connected to individual photosensors and a daylight harvesting strategy sought[3].

**2.** The Photocell control system shall have the following characteristics:

[3] Openness-to-wall ratio is defined as the area of the vertical plane of the structure (wall) that is open (e.g., fenestration, not enclosed and open to the air/environment) compared to the area of the wall that is solid/opaque.

**a.** 15 to 30 second built-in time delay to prevent response to momentary lightning flashes, car headlights or cloud movements.

**b.** Set the sensor set point to energize the lighting system when daylight and the electric lighting provide less than 10 footcandles on the parking surface below the sensor. When more than 10 footcandles is provided on the parking surface below the sensor for more than 30 minutes, turn off the electric lighting connected to the sensor.

**c.** Mounted in an un-obscured location for measuring the daylight and electric light on the parking surface with a separate control/calibration module mounted separately and in an accessible location.

**d.** Use relays that are UL 773 or UL 773A listed and designed to fail in the "on" position.

**3.** Luminaires located in the vehicle entry/exit area needed during daylight hours shall be connected to either a photosensor or astronomical timeclock to reduce the lighting in this area during non-daylight hours.

B. Occupancy Sensor Controls

**1.** Install one occupancy sensor per luminaire and aim sensors in locations to achieve coverage of areas indicated. Coverage patterns shall be de-rated as recommended by manufacturer based on mounting height of sensor, column locations, and dropped beams. Do not simply use gross rated coverage in manufacturer's product literature.

**2.** Occupancy/vacancy sensors shall comply with NEMA Standard WD 7-2000 which provides for testing requirements on the issues of performance sensitivity.

**3.** Sensor Type: Infrared or ultra high frequency (microwave). Detect occupancy by sensing a change in sensor pattern in area of coverage.

**4.** Sensors shall be located or shielded or controlled by software to adjust sensitivity based on ambient temperature or air temperature variations.

**5.** Sensor must incorporate a failsafe feature such that lamps fail "on" in the event of sensor failure.

**6.** Occupancy sensors can either dim or switch the luminaires from a "high" to a "low" setting or from on to off. Site owner to specify.

## **PART 3 –** EXECUTION

### 3.1 INSTALLATION

A. Disconnect all power sources prior to installation.

B. Follow manufacturers' recommended installation procedures.

## 3.2 TESTING & COMMISSIONING

A. Ultrasonic sensors should have their sensitivity adjusted when interference from air movement is at its maximum.

## 3.3 MANUFACTURER SERVICES

A. Manufacturers must provide installation and troubleshooting support via telephone.

END OF SECTION

# Appendix A – Definitions and Related Terms

Coefficient of Variation (CV):

This method is a measure of the weighted average of all relevant illuminance values and is commonly used in statistics, where the variance of a set of values is calculated as the ratio of standard deviation $s$ of all values to the mean $x$.

$x_i$ = illuminance at point i,
N = number of points measured
$\bar{x}$ = mean illuminance

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{n}}$$

$CV = \sigma / \bar{x}$

# Appendix B – LED Reliability

| Test | Reference Standard |
|---|---|
| Room Temp Operating Life Test (RTOL) | JEDEC JESD22-A108-C or JEITA EIJA ED-4701/101 |
| High Temp Operating Life Test (HTOL) | JEDEC JESD22-A108-C or JEITA EIJA ED-4701/101 |
| Low Temp Operating Life Test (LTOL) | JEDEC JESD22-A108-C or JEITA EIJA ED-4701/101 |
| Wet/Humid Operating Life Test (WHTOL) | JEDEC JESD22-A108-C or JEITA EIJA ED-4701/102 |
| Low Temp Storage | JEDEC JESD22-A108-C or JEITA EIJA ED-4701/201 |
| High Temp Storage | JEDEC JESD22-A108-C or JEITA EIJA ED-4701/202 |
| Humid & High Temp Storage | JEDEC JESD22-A108-C or JEITA EIJA ED-4701/103 |
| Thermal Shock (Cycling) | JEDEC JESD22-A104-D or JEITA EIJA ED-4701/105 |
| Mechanical Shock | JEDEC JESD22-B104-C or JEITA EIJA ED-4701/403 |
| Electrostatic Discharge (ESD) | JEDEC JESD22-A114-F or JEITA EIJA ED-4701/304 |
| Corrosion (Salt Spray) | JEDEC JESD22-A107-B or JEITA EIJA ED-4701/204 |
| Moisture & Reflow Temp Test | JEDEC J-STD-020D.01, or JEITA EIJA ED-4701/104 *and* JEITA EIJA ED-4701/301 |

## Appendix C – Lamp Lumen Depreciation Calculations Standard Exponential decay curve fit process

A. A standard exponential decay function (e.g.,) must be used to estimate the lumen degradation of the LED module/array. The LM-80-08 data must be graphed per temperature to determine the exponential decay of the data. This can be done in various software programs and must take the form of:

$$L=L_0e^{-\alpha t}$$

Where:

1. L = light output at "t" hours
2. $L_0$ = % of initial light output at 1000 hours
3. e = natural logarithm
4. $-\alpha$ = a solved constant.
5. t = time of data point

# Appendix D – Sample Parts of the Parking Structure

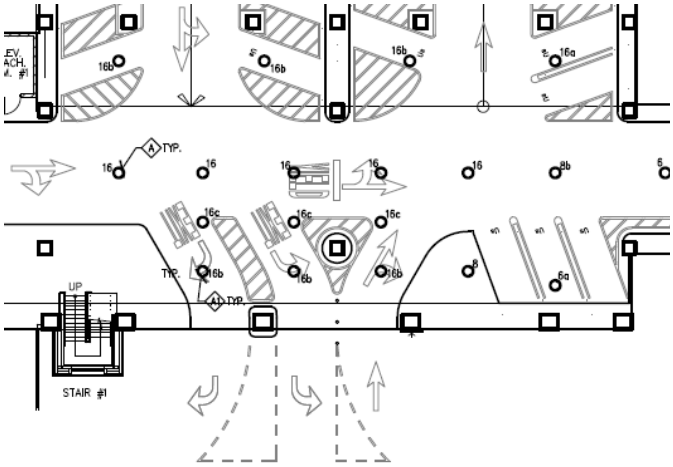


Figure 1 – Covered Vehicle Entry/Exit

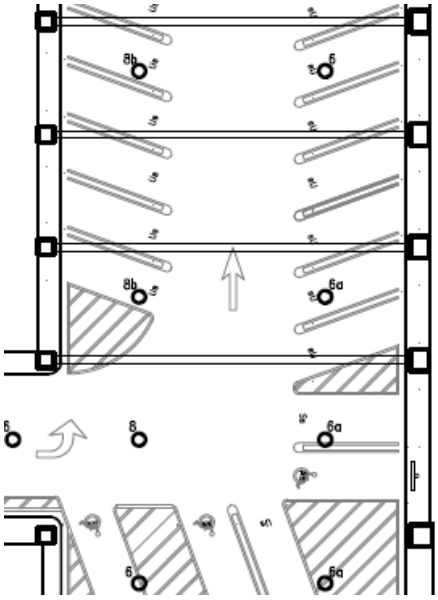

Figure 2 – Covered Parking Area

# Appendix D – Sample Manufacturer Submittal Information
# Manufacturer should highlight this information when submitting to site

Luminaire Submittal #1 – Physical Description
Luminaire is 18” wide x 18” long x 6” deep. The luminaire is constructed of die-cast aluminum with a powder-coat finish. Luminaire weighs 15 pounds. Means of mounting luminaire.

Luminaire Submittal #2 – Driver Information
Philips/Advance Transformers – LED120A0024V10D
Input Power Max (W): 31.9
Output Power (W): 25.5
Driver Efficiency: 25.5 / 31.9 = 79.9%
Min. / Max/ Ambient Temperature: -40° C / 60° C

Luminaire Submittal #3 – Lighting Facts Label


Luminaire Submittal #6 – Coefficient of Utilization

**Coefficients Of Utilization - Zonal Cavity Method**
Effective Floor Cavity Reflectance 0.20

| RC | 50 | | | 30 | | | 10 | | | 0 |
|---|---|---|---|---|---|---|---|---|---|---|
| RW | 50 | 30 | 10 | 30 | 10 | 0 | 50 | 30 | 10 | 0 |
| 0 | 111 | 111 | 111 | 106 | 106 | 104 | 102 | 102 | 102 | 100 |
| 1 | 93 | 89 | 85 | 85 | 82 | 79 | 85 | 82 | 80 | 77 |
| 2 | 76 | 69 | 63 | 67 | 62 | **57** | 70 | 65 | 60 | 58 |
| 3 | 63 | 55 | 48 | 53 | 47 | **41** | 57 | 51 | 46 | 44 |
| 4 | 53 | 44 | 37 | 43 | 37 | 31 | 48 | 42 | 36 | 33 |
| 5 | 46 | 36 | 29 | 35 | 29 | 23 | 41 | 34 | 29 | 26 |
| 6 | 40 | 31 | 24 | 30 | 23 | 16 | 36 | 29 | 23 | 21 |
| 7 | 35 | 26 | 20 | 25 | 19 | 13 | 32 | 25 | 19 | 17 |
| 8 | 31 | 23 | 16 | 22 | 16 | 12 | 29 | 21 | 16 | 14 |
| 9 | 28 | 20 | 14 | 19 | 14 | 9 | 26 | 19 | 14 | 12 |
| 10 | 26 | 18 | 12 | 17 | 12 | 5 | 24 | 17 | 12 | 10 |

Luminaire Submittal #7 – Luminaire Efficacy

- Initial Lumens: 6011
- Input Power: 63W
- Luminaire Efficacy: 95 LPW

Luminaire Submittal #8 – Target Efficacy Rating (TER) Calculation

- Initial Lumens: 6011
- Ballast Factor: 1.0 (LED Device)
- CU 30/0/20 RCR 2: 57
- CU 30/0/20 RCR 3: 41
- CU 30/0/20 Average: 49
- Input Power: 63W
- TER: 6011 x .49 / 63W = 47 LPW

Luminaire Submittal #9 – Table of zonal lumen output

| Zone | Zonal Lumens | Percent of Total Luminaire Ouput |
|---|---|---|
| | | |
| 0-10 | 59.949 | 1.00% |
| 10-20 | 190.1865 | 3.16% |
| 20-30 | 209.424 | 3.48% |
| 30-40 | 389.31 | 6.48% |
| 40-50 | 1044.692 | 17.38% |
| 50-60 | 1610.0307 | 26.78% |
| 60-70 | 1589.0928 | 26.43% |
| 70-80 | 843.3712 | 14.03% |
| 80-90 | 75.51 | 1.26% |
| 90-100 | 0 | 0.00% |
| 100-110 | 0 | 0.00% |
| 110-120 | 0 | 0.00% |
| 120-130 | 0 | 0.00% |
| 130-140 | 0 | 0.00% |
| 140-150 | 0 | 0.00% |
| 150-160 | 0 | 0.00% |
| 160-170 | 0 | 0.00% |
| 170-180 | 0 | 0.00% |

Luminaire Submittal #10 – Correlated Color Temperature

- CCT: 4152 K
- Duv tolerance of 0.002

Luminaire Submittal #11 – Color Rendering Index

- CRI: 82

# Appendix E – Ambient Temperature Information

Table 1 – Number of days with minimum temperature below 32° F

| Location | # of Days | | | | |
|---|---|---|---|---|---|
| Flaggstaff, AZ | 209 | Chicago, IL | 131 | Charlotte, NC | 63 |
| Phoenix, AZ | 6 | Indianapolis, IN | 116 | Oklahoma City, OK | 78 |
| Los Angeles, CA | 0 | Wichita, KS | 109 | Portland, OR | 43 |
| Fresno, CA | 21 | Louisville, KY | 88 | Eugene, OR | 55 |
| Sacramento, CA | 16 | New Orleans, LA | 14 | Charleston, SC | 33 |
| San Francisco, CA | 2 | Shreveport, LA | 37 | Nashville, TN | 76 |
| Denver, CO | 155 | Kansas City, MO | 111 | Dallas, TX | 39 |
| Jacksonville, FL | 15 | Jackson, MS | 49 | Houston, TX | 19 |
| Orlando, FL | 2 | Las Vegas, NV | 30 | Salt Lake City, UT | 123 |
| Atlanta, GA | 52 | Reno, NV | 166 | Richmond, VA | 84 |
| Savannah, GA | 28 | Albuquerque, NM | 116 | Seattle, WA | 31 |

Note: Table 1 is Table 9-9 from *Parking Structures: Planning, Design, Construction, Maintenance and Repair* by Chrest et al. The source for the data is from the National Weather Service Climatological Data Center